Board 326: Investigating Creativity, Confidence, and an Entrepreneurial Mindset through Curricular Modification and Community Engagement

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Investigating Creativity, Confidence, and an Entrepreneurial Mindset Through Curricular Modification and Community Engagement

In the Spring of 2022, the South Dakota Mines Department of Materials and Metallurgical Engineering faculty modified their junior-level Principles of Metallurgical Design course to utilize local Black Hills minerals to formulate and produce a clay-based ceramic body. The final body functionality was left to the student teams to help create an open end to the design process. The course provided a unique learning environment for students and faculty. The students learned the iterative design process through this project-based learning approach as well as the unique challenges that the use of local minerals present. It was found that the use of clay-based ceramics in design lends itself well to the teambuilding process. In addition, the faculty learned the importance of targeted messaging within a STEAM framework to enhance student project acceptance and creativity.

For the Spring of 2023 (second year), the faculty team will focus on leveraging their initial pedagogical experience by executing a very similar design project as the previous year. Additional emphasis will be focused on product development, and the ability for the teams to design an economically-viable product that could be mass produced. The faculty team will assess student creativity, confidence, entrepreneurial mindset, and technical knowledge at the beginning and the end of the semester.

Concurrent with the curricular modification the faculty team has begun expanding the program through new undergraduate course development (MET 300), and focused community STEAM activities that engage pre-Kindergarten to retirement age participants.

Program Background

The Art + Engineering (A+E) program at South Dakota Mines is a unique program that has been integrated into all learning levels [1] of the Metallurgical Engineering curriculum. The field of Metallurgical Engineering has a non-diverse professional makeup. Our program mimics that profile and has additional challenges associated with our rural location and relatively narrow disciplinary focus. Consequently, our programmatic elements focused on making creativity, innovation, collegiality, entrepreneurship, and critical thinking components within the A+E program.

The terms "Art + Engineering" may be associated with STEAM, the concept of infusing Art into Science, Technology, Engineering, and Mathematics (STEM) learning environments. As the A+E program is primarily housed in Metallurgical Engineering, we consequently chose the A+E moniker to subtly distinguish our efforts from the larger STEAM movement. One the leaders of the STEAM concepts at a university level, Dr. John Maeda, stated that, "*I believe art and design are poised to transform our economy in the 21st century like science and technology did in the last century*" [2], and consequently, we have focused significant A+E effort on our Junior-level design course.

Two goals for the A+E team at South Dakota Mines university are to *i) increase student innovation, creativity, collegiality, and entrepreneurship within STEM programs*, and *ii) increase the talent pool of STEM graduates, by engaging and retaining traditionally underrepresented STEM participants that can help integrate art into products, primarily in the design cycle*.

To help meet the above goals the A+E program involves an Artist-in-Residence (AIR). The AIR provides professional opinion and expertise with regard to new A+E modules within the program. Thus, the AIR provides a diverse and out-of-the-box perspective on many of the problems the students face.

With regard to Goal #1 increased student innovation, creativity, collegiality within the STEM programs at South Dakota Mines, the team has made significant progress. STEAM integration herein is being approached in various formats in different courses, see Table 1. This process began in the Fall of 2021 with the integration of new relevant content into Structure and Properties of Materials Lab (MET 231) and Introduction to Metallurgical Engineering (MET 110) courses. For the MET 110 course, the first-year students completed a sketching module, which then translated to crystal structure and 3D Printing modules. Students also participated in other kinesthetic learning modules that included creating glass pendants, learning welding techniques, and casting artistic aluminum pieces.

In the Spring of 2022, the program integrated STEAM curricular activities in a junior-level course, Principles of Metallurgical Design (MET 352). The integration for this course focused on the creation and design of a functional and aesthetically pleasing product based upon local (Black Hills) minerals. The students comminuted (crush, grind, classify), characterized, formulated, and formed clay-based ceramic bodies from the minerals. Throughout this process the students used scientific resources (e.g., x-ray diffraction (XRD)) to optimize their formulation. To facilitate this process faculty delivered new course modules on i) minerals for ceramics, ii) rheology of clays

and iii) fluxes, glazes, and vitrification. Additionally, the program AIR gave a technical kinesthetic lecture on clay forming (e.g., coil, pinch, etc.).

In the Fall of 2022, the MET 110 course was modified from a 1 credit offering that meets twice a week for 1 hour to a 3-hour lab that meets once a week. This modification allowed for better fluidity between kinesthetic modules (welding, casting, glass pendant making), and allowed for an industry tour. The STEAM integration (modules) was very similar to Fall 2022 semester, but the delivery (3-hour block) was modified. In MET 231, the same Metal Clay lab was offered as in prior semesters.

Table 1: Outline of courses prior to and after the NSF IUSE program integration.

Course	Before NSF IUSE program	After NSF IUSE program
MET 110 *Fall 2021 integration*	Curricula included guest speakers, campus tours, blacksmithing, resume building, student success visits, etc. A term project which included optical microscopy.	New curricula included hand sketching crystal structures, 3D printing, casting, welding, metal clay, industry visit, and glass working modules.
MET 231 *Fall 2021 integration*	Curricula included grain size, optical microscopy, ASTM standard testing included (Charpy, hardness, and tensile testing), and blacksmithing.	New curriculum was a hand drawn sketch of an object the student would design and create from metal clay. The students would have to account for the effect of shrinkage during the sintering process.
MET 352 *Spring 2022 integration*	Curricula included a semester long design course where two faculty would advise multiple teams. The course is a lecture/lab course and all the lecture portions solely focused on design topics (teaming, design process, literature review)	Faculty from the department gave additional technical lectures relevant to the design project (e.g., ceramic formulation, processing, sintering, etc.). Each team was paired with a single advisor.
MET 220/L *Spring 2022 integration*	Curricula includes mineral processing including comminution, sizing, froth flotation, gravity separation, electrostatic separation, magnetic separation and flocculation.	New curricula included a lab module focusing on mineral processing in which the students create a pinch pot from mineral processed clay.
MET 464 *Fall 2022 integration*	Curricula included senior students with a faculty advisor paired up with an industrial partner to solve an industrially relevant problem.	New curricula focused on feldspar mineral processing circuit. The feldspar products are highly used by the artistic community
MET 300/L *Spring 2023 integration*	Curricula is new as this course did not exist prior to the funding of this grant. The course is currently ongoing as of Spring of 2023. This course and MET 400 (see below) are required classes in the new Ceramic Engineering Minor at South Dakota Mines.	The course (Applied Glass and Ceramic Engineering) introduces students to ceramic and glass topic ranging from clay to concrete to stained glass to ceramic processing. To-date, the students have interacted with two professional artists.
MET 400	Curricula is new as this course did not exist prior to the funding of this grant	This course will be offered for the first time in Fall of 2023.

The senior design series offered is a two course sequence. This is directly relevant to Goal #2 (*increase the talent pool of STEM graduates, by involving traditionally underrepresented STEM participants that can help integrate art into products, primarily in the design cycle*). The design teams are paired with a faculty advisor and an industrial partner to solve a problem or challenge the partner faces in their company. The student teams engage in weekly to bi-weekly meetings with the industrial partners. This academic year (starting Fall of 2022), one of the senior design teams engaged with a local mineral processing company, Pacer Minerals. Pacer Minerals is one of the leading producers of Custer Feldspar. Feldspar is a key ingredient in many ceramic materials and pottery (dishes, cups, etc.) and the ceramic coatings (glazes) that strengthens those materials. The senior design team was tasked with analyzing the feldspar processing circuit to improve particle size distribution, minimizing coarse and fine particles, to assist in improving the material properties of ceramic products (pottery) and prepare pieces for ASTM testing [4-7].

In the Spring of 2023, the new MET 300: Applied Glass and Ceramic Engineering course is being offered. The course includes two hours of lecture and a three-hour lab each week. The lecture focuses on ceramic materials (glass, clay bodies, refractories), specifically their chemical structure, and how that impacts processing, manufacturing, and performance of these materials. The lab focuses on applying knowledge from the lecture. To date the students have prepared ceramic samples to perform ASTM testing including microhardness, 3-point bend testing and optical microscopy [4-7]. The lab has also allowed the AIR to deliver a historical and traditional clay processing module that focuses on throwing on a potter's wheel [8] and slab rolling [9]. The students also learned slip casting, but in a separate module. Each student submitted one of their clay processed (wheel or slab) products to the annual campus Student Art Competition [10]. In addition, the students visited companies related to the local ceramic/aggregate industry to help put their classroom/laboratory training into context [11].

In addition to the new MET 300 course, some modifications in MET 352 were made from Spring 2022 to Spring 2023. These are discussed in detail in the following section.

Spring 2023 MET 352: Introduction to Metallurgical Engineering Project Background

The institution is a primarily undergraduate institution that rests in a geologically diverse region of the United States. For example, western South Dakota minerals include granite (Mount Rushmore and Crazy Horse Monuments), sandstone, limestone, shale (Badlands region) and pegmatite ore (feldspar, quartz, mica). The diversity of minerals composing the landscape provide a unique opportunity for students to literally work with minerals from their own backyards.

For this discussion, the focus is the integration of art into the junior design course (MET 352 Principles of Metallurgical Engineering Design). The assigned project for the course was to design and successfully test a process whereby aesthetic and non-toxic ceramic can be fabricated out of local minerals. The final design product should include all the materials, forming and processing conditions (e.g., wt% of minerals, order of processing times and temperatures) required of a final demonstration piece.

The students were provided a modicum of samples of six local minerals. The mineral samples provided were collected from locations i) on campus, ii) within the community, and iii) from local mineral producers. All samples were analyzed using x-ray diffraction (XRD), which provided to

the students the minerology of the samples. As expected, the so called 'wild-clay' samples collected from around campus and the community were more diverse mineralogically than the samples from the mineral producers. With the XRD information, the students are then able to formulate a ceramic product that can withstand high firing temperatures, and potentially be further leveraged into a glaze to coat the ceramic product and increase the durability. For this course, the primary source for the students was the text *Science for Potters* [3].

The open-ended nature of the problem statement provides the teams of students the opportunity to create a diverse array of products that can be created from the local minerals. These can be seen by the wide range of products created by the MET 352 teams in the Spring of 2022. In Figure 1, the design competition winners can be seen, a metric based on scientific merit and creativity was utilized to determine the winner(s), see Table 2.

Table 2: MET 352 Principles of Metallurgical Design Project Competition Rubric

Creativity and Originality	Score	Comments
Proper labeling: type of ceramic product, name of ceramic product, team	/5	
Proper dimensions	/5	
Final piece execution (aesthetics, use of colors, etc.)	/5	
Ceramic product choice addressed, other adjacent work (slip casting, mineral processing, etc.)	/5	
Effort/Difficulty Level		
Difficulty level of process attempted: complexity of clay formation, complexity of glaze formation, complexity of product, design	/10	
Creativity and originality	/10	
Team spirit	/10	
Total	**/50**	

For example, in Figure 1a, the students created a replica of the school mascot, Grubby, by creating an inverse plaster mold that the clay formulation could be slip casted into. The team designed a ceramic production process that required comminution of Belle Fourche Shale (found on hills surrounding campus) and slurry formation that could then be slip cast and fired into ceramic. When the teams proposed the Belle Fourche Shale Grubby as their design product, the AIR cautioned the students that their proposed product would be *"very challenging due to the complexity of the Grubby features".* Specifically, the AIR mentioned the overhangs of the brim of the Grubby hat to his nose to his holster. In other words, the AIR thought the students would encounter processing challenges. Even though the team picked a very complex design, the students successfully slip casted a very detailed Grubby, see Figure 1a. The AIR upon seeing the product at the end of the term expressed her appreciation that the team was able to successfully execute such a challenging mold that seasoned artists may struggle to execute. Additionally, she stated that this product was a wonderful merger of art and engineering into a creative product.

Figure 1: Spring 2022 MET 352 scientific and creative competition winners. (a) Slip casted Grubby, the South Dakota Mines school mascot, (b) slip casted mug of the department head (Dr. Michael West).

The mug shown in Figure 1b was the other first place winner of the design competition. The mug is a replica of the Department Head's (Dr. Michael West) actual head. The students used use a 3D scanner to produce a model of Dr. West's head to be used for the overall design. This model was then 3D printed (plastic) and a plaster mold was made from the 3D print. The mold had to be modified slightly (draft angles) for the casting to be removed from the mold successfully. Most of the modification was in the handle. In addition to the multiple media platforms (digital and physical) that were used, the team also created their own glaze (versus purchasing a commercial glaze). The Department Head team chose to constrain their project to formulating an effective and aesthetic glaze that solely used materials from the Black Hills, as it added additional creative and technical challenges to overcome.

The scientific and creativity rubric that was used to for the MET 352 competition can be seen in Table 2. The students were evaluated by program faculty and the AIR. The students also received direct feedback (comments) from the evaluators.

Spring 2022 MET 352– Results and Lessons Learned

The A+E team goal for the MET 352 course was to have the student teams design and produce (formulate, fire, glaze) a unique ceramic body. In that regard, the design goal for MET 352 was a success as all teams successfully designed and fabricated prototypes. One point of reflection for the PIs after the term was complete was the reproducibility or manufacturability of the products. The two winners in the competition were complex, creative, and novel pieces. However, they are essentially and uniquely, "one-of-a-kind prototypes". At the time of the competition there was one complete Grubby (Figure 1a), and three Dr. West mugs (Figure 1b). Other teams produced a set of nesting bowls (four bowls in total), a teacup, and a set of six shot glasses. The shot glasses were one of the designs that could quite easily be mass produced, while the other items were not amenable to production scaleup.

One method used to assess the MET 352 course was a structured interview process called Small Group Instructional Diagnosis (SGID) [12]. SGID was offered midway through the Spring of 2022 term to help facilitate improvements in the course as well identify items that are helpful to student learning. The SGID is performed by an external assessor, not the course instructor. The PIs requested that the SGID focus on course modifications which included a stronger emphasis on innovative design components. The external assessor requested the students provide thoughts as to the benefits and detriments of these components.

The assessor determined that in general, students felt the design experience has merit, but had two concerns with implementation. First, some, but not all students, had experience in ceramics or ceramic engineering processes. For those that did have that background the design process would be more readily implemented. For those without such background it is difficult to envision how to apply engineering thinking to the design project. For most of this latter group of students the project seemed to become more of an art project for art's sake and less of an opportunity to incorporate innovative engineering design. The second concern noted from the SGID was that the design objectives seemed to be unclear to some of the students. While related to the first concern, this concern is separate and distinct and was a consistent theme for a majority of the students. Because most did not feel they had the appropriate ceramics background they wondered if introducing this project was premature and might be better received next year when more of the students had a more complete background.

A significant lesson learned from the SGID was to focus on messaging (word choice) to the students. Given the SGID assessment a few key terminology changes will be implemented in the spring of 2023. One of the big changes regarding word choice is not using the word "art" in design project descriptions, course assignments, or conversations with the students. Utilizing art in the description of items tended to elicit a negative emotional response from some of the students who have developed an aversion to this form of expression. Instead of using the word art, the A+E team decided to reframe sentences when talking with students to use words such as creativity, innovation, and entrepreneurial mindset. The funded NSF IUSE grant was intended to increase student creativity and innovation with art as the conduit, so this change in messaging is consistent with the intent of the award. Along that same theme, the A+E team chose to minimize using art

terminology and focus on scientific/engineering terminology. For example, instead of using the words like "pottery", the word "ceramic body" or "ceramic material" will be used in the future.

Current Results and Applying Lessons Learned from Spring 2022 to Spring 2023

At time of submission, the students are in Week 6 of a 15-week semester, and the students have not completed the design process, but some preliminary self-efficacy studies have been performed. The MET 352 design project from the Spring of 2022 is the same as the design project from Spring of 2023. However, the Spring of 2023 has a new emphasis on the scalability of the design such that approximately 100-piece batches of these pieces could be made for give away or sale as a potential marketing effort.

The delivery and schedule of the design topics and technical lectures are the same for Spring 2022 and Spring 2023. Preliminary results of some of the focused activities are underway. Specifically, the teambuilding proto-typing module led by the AIR. The AIR covers three common forming processes (pinch, coil, and slab building) for ceramic clay bodies. The self-efficacy of the student's prior to and after prototyping was assessed, Figure 2.

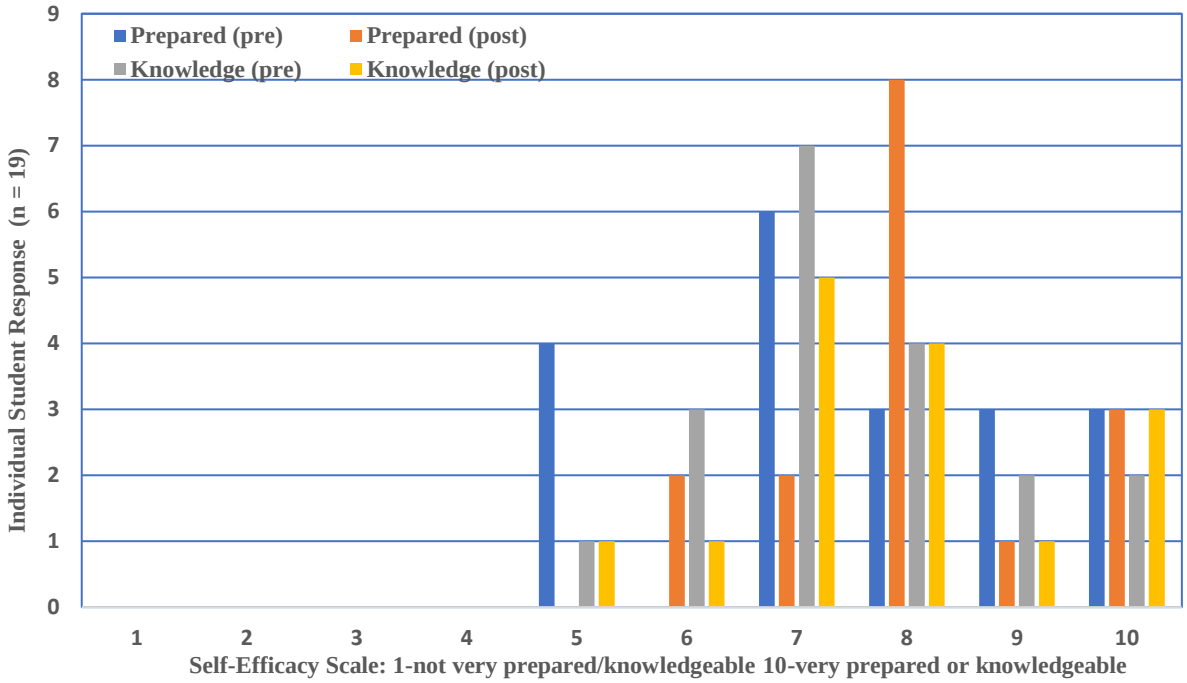

Figure 2: Self-efficacy of the 2023 MET 352 students prior to completing the module and after completing the module.

In Figure 2, two questions were asked of the students that focused on the student's feeling prepared to build a prototype and their assessment of their knowledge having completed a prototype. The two questions are explicitly written below.

Q1. Do you feel prepared for the team building proto-typing activity?

Q2. Do you think the team building prototyping will help with your understanding of the technical aspects of the project and improve your understanding of ceramic material properties?

The overall trend from Figure 2 suggests that the students felt more prepared for designing their product after completing the prototyping module. Notably, there were ten students (~52% of the class) with a preparation score between 5 and 7 prior to completing the prototyping module. After completing the module, only four students had a score between 6 and 7, and there were no longer any students with a score less than 6 for assessing their preparedness. Also of note is that a decrease of two students from a score of 9 between the pre and post module was observed. Although, an overall trend positive increase would be ideal, the dip in this number may be just to a single lower number, 8, as there was a large increase from 3 students to 8 students who assessed themselves as an 8.

Iterations of a product is a common part of the design process. However, a key portion of this particular module was prototyping. Each team entered the module with a design approach and fabrication method in mind so they could proto-type their product. The students may have scored themselves high as they had envisioned a specific processing pathway that was going to be viable. However, upon executing their prototype ceramic clay body, the individuals may have discovered that the product was not as easily produced as was initially thought. If this is the case, the team may need to rethink their fabrication or processing approach. Note, there would be cause for concern if an increase in lower numbers (1-4) was observed post module indicating that the students are feeling not prepared. However, all the post prototyping values were at 6 and above, indicating a high level of preparation confidence in the individual student responses. Another key thing to note is that the design project within MET 352 is a team effort, so although some individual responses may be lower there is the strong likelihood that team members evaluated themselves much higher.

In a material engineering field touching and feeling the material (physical interaction) is vital. Until this point in the course, the students have not been required to touch any of the materials, some have taken inspiration to go explore in the lab, but no assignment requiring. The proto-typing module is the first physical interaction the students have with clay, and specifically commercial clay that has been optimized for human use. This is a "best case" scenario for the students, as the clay they will be using is a result of their own formulation and constrained material selection, which may require some modifications. Overall, the students had a positive feeling regarding their knowledge prior to and after the proto-typing module. Prior to proto-typing four students reported scores of 5 and 6. After the proto-typing module, the number of students reporting 5 and 6 decreased from four to two students.

Another important comparison is between the 2022 and the 2023 cohorts, the comparisons can be seen in Figure 3 and Figure 4A couple key items to consider between the cohorts is that the 2022 cohort did not have as much high-temperature processing exposure (e.g., sintering, vitrification, slags, calcining) as the 2023 cohort does. The disparity between the two is due to the Metallurgical Engineering Department course scheduling that is on an odd and even year offering for certain classes.

In Figure 3, Question 1 regarding preparation post proto-typing team building is plotted with the student responses of both the 2022 and 2023 cohort. There were 21 responses for the 2022 cohort and 16 responses for the 2023 cohort. The 2023 cohort had zero student responses below 6 (two students responded with a score of 6) after the proto-typing module. The 2022 cohort had six students (~29% of the class) respond with a score of six or less.

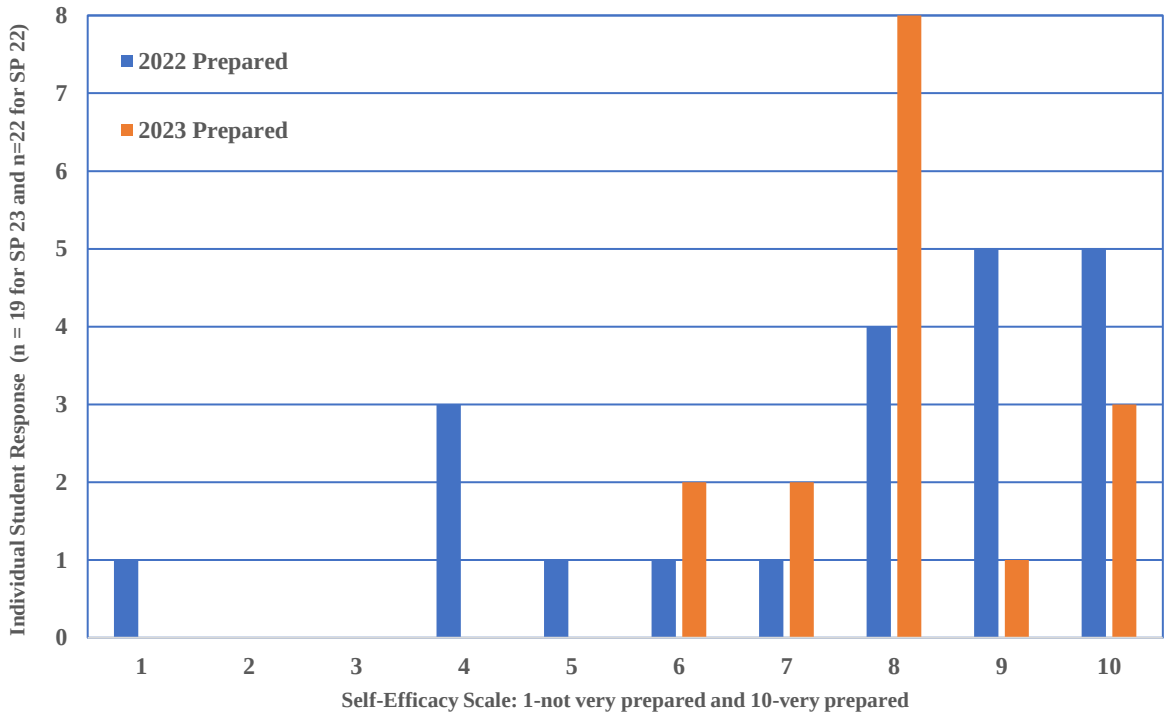

Figure 3: Individual student's self-efficacy responses regarding project preparation from the MET 352 Spring 2022 and Spring 2023 cohorts.

As previously discussed, there were some minor changes that helped change the student's self-efficacy regarding the preparation of the project. The first is subtle word changes. In Spring of 2022, the module was described as "clay working and team building module", whereas in the Spring of 2023, the module was described as "product prototyping and team building module". Although what was done in the module, which at its simplest was working clay, was not vastly different between the two years, the biggest difference was the messaging. The second change was that equipment (kiln, slab roller, pug mill and pottery wheel) that was ordered in Fall 2021 for Spring 2022 classes came in much farther behind schedule than originally anticipated. The third item is not so much a change as an observation. The Spring of 2022 cohort seemed somewhat skeptical that the design could be executed. Although, they had proof of objects that the faculty had created with local clay, they had yet to see a student create an object from local clay. Thus, the 2022 cohort items were placed in a prominent display case for inspection by the 2023 cohort.

In Figure 4 which focuses on student's response to knowledge gained, a similar trend was observed as in Figure 3. The question asked is Question 2 above which focuses on knowledge and a better technical understanding of the material. The 2022 cohort once again showed much lower

individual scores after the prototyping team building module than the 2023 cohort. Using 5 and 6 as the dividing point between low and high scores, respectively, the 2023 cohort only had one student (~6% of the class) score themselves on the low side. The 2022 cohort had eight students (~38% of the class) that scored themselves on the low side. Many of the potential reasons for this imbalance in the student's self-efficacy has already been discussed above and can be applied to the data below.

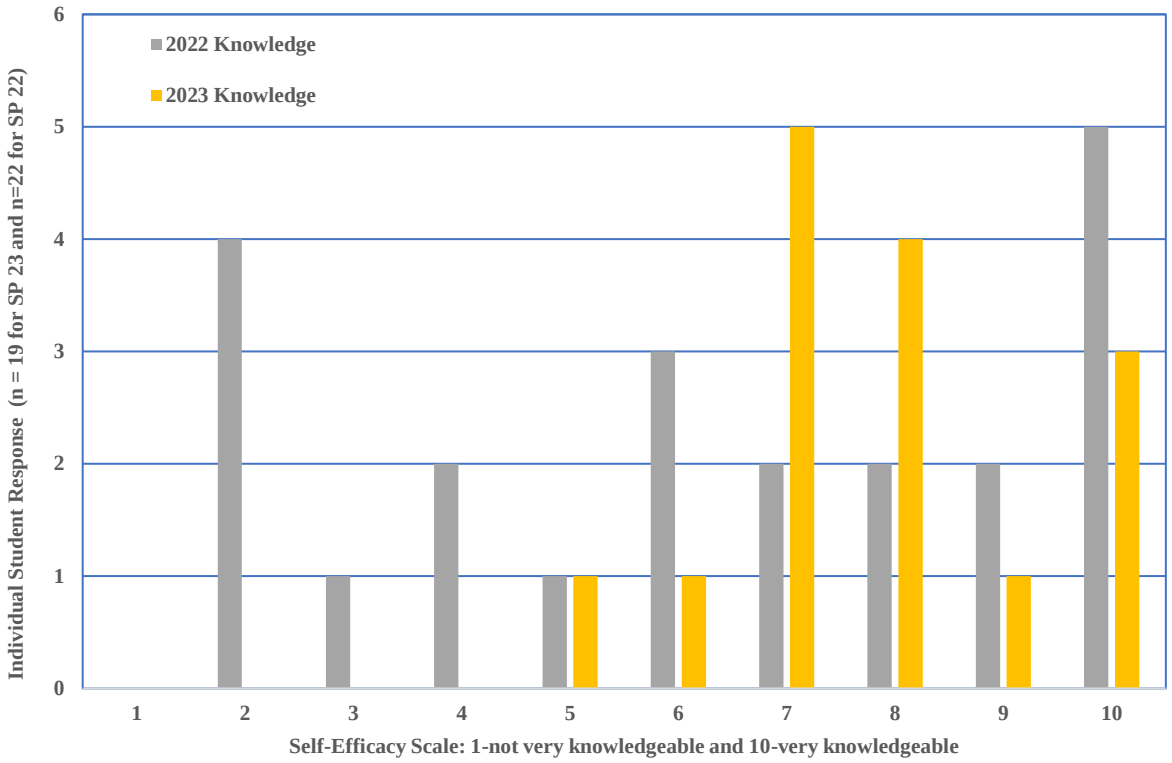

Figure 4: Individual student's self-efficacy responses regarding technical knowledge required for the design project from the MET 352 Spring 2022 and Spring 2023 cohorts.

Community STEAM Outreach

The A+E team led multiple STEAM outreach activities that engaged the local and state-wide communities at many different ages and levels. One very notable activity that engaged an older generation (post college) of students was an A+E community mixer at the local economic development incubator. The mixer included a keynote speaker, Professor Quintin Owens, that discussed his artwork that merges traditional art and engineering boundaries. The audience included community members from engineers to artists to college students, see Figure 5a.

Another impactful community outreach activity was the delivery of a kinesthetic metal clay module to the high school teachers at a state-wide STEM Educator Conference (Huron, SD), see Figure 5b. The module was delivered through multiple session of K-12 teachers. The metal clay module was reported on the front page by the local newspaper, Huron Plainsman [13].

In the summer of 2022, an A+E high school summer camp, Science of Pottery & Glass was piloted [14], see Figure 5c. The camp was composed of six high school students (five female students and one male student), and two community members (not shown in Figure 5c). The program attendees left the camp with a Pottery and Glass binder and multiple glass and pottery products – some of which they produced themselves. The camp was a great springboard for the one-day A+E Workshop [15] for K-12 teachers that will be offered summer of 2023 to middle and high school teachers.

Figure 5: Pictures from various STEAM outreach activities a) A+E mixer at Elevate with many individuals mixing, b) Image from the local newspaper of the A+E Metal Clay session of the South Dakota STEM Ed conference in Huron, South Dakota [13] c) local cement company, GCC, plant tour for the high school students of the Science of Pottery & Glass summer camp [14].

Conclusions

The A+E team has made good progress in the second phase (approximately halfway through the three-year award) of the NSF IUSE grant. The results from the MET 352 design course demonstrate both an integration of art into the curriculum by defining a project that has the product be an artistic or at least an aesthetically pleasing. Growth in delivery by the A+E team can be seen by the shift in the student's perspective from the self-efficacy surveys.

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Coeur Wharf Mine – MET 352 clay samples
Elevate Rapid City – Hosting the A+E Mixer

References

[1] Donovan, K., & Kellar, J., & West, M., & Birrenkott, C., & Kellogg, S., & Mitchell, D., & Whitehead, M. (2022, August), *Investigating the Impact of Arts on Student Learning by Introducing Glass Science in the Materials Engineering Curriculum* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, MN. https://peer.asee.org/42059

[2] J. Maeda, "STEM to STEAM: Art in K-12 is Key to Building a Strong Economy." *Edutopia: What works in education. 2012* https://www.edutopia.org/blog/stem-to-steam-strengthenseconomy-john-maeda accessed 1/16/2021

[3] Bloomfield, L. (2017). Science for potters. The American Ceramic Society. Westerville, OH.

[4] *Standard practice for fractography and characterization of Fracture Origins in Advanced Ceramics*. ASTM International - Standards Worldwide. (n.d.). Retrieved February 22, 2023, from https://www.astm.org/c1322-15r19.html

[5] *Standard test method for flexural strength of advanced ceramics at ambient temperature*. ASTM International - Standards Worldwide. (n.d.). Retrieved February 22, 2023, from https://www.astm.org/c1161-13.html

[6] *Standard test method for flexural strength of advanced ceramics at ambient*. (n.d.). Retrieved February 22, 2023, from https://sites.utexas.edu/taleff/files/2019/10/astm_c1161_13.pdf

[7] *Standard test method for Vickers indentation hardness of advanced ceramics*. ASTM International - Standards Worldwide. (n.d.). Retrieved February 22, 2023, from https://www.astm.org/c1327-15r19.html

[8] Moorey, Peter Roger Stuart (1999). Ancient Mesopotamian Materials and Industries: The Archaeological Evidence. Winona Lake, Indiana: Eisenbrauns. P 146. ISBN 9781575060422.

[9] Shukurov, Anvar; Sarson, Graeme R.; Gangal, Kavita (7 May 2014). "The Near-Eastern Roots of the Neolithic in South Asia". *doi:10.1371/journal.pone.0095714*. *ISSN 1932-6203*

[10] Whitehead, M. (2020, January 29). *Annual Student Art Show*. Facebook: Apex Gallery. Retrieved February 22, 2023, from

https://www.facebook.com/APEXGallery/photos/pb.100057184221552.-2207520000./2865821416809615/?type=3

[11] *Pioneering the Future*. Simon Team. (2018, June 14). Retrieved February 22, 2023, from https://simonteam.com/

[12] Seattle University. (n.d.). *Center for Faculty Development*. Seattle University. Retrieved February 22, 2023, from https://www.seattleu.edu/faculty-development/services/learning-and-teaching/small-group-instructional-diagnosis/#:~:text=What%20is%20a%20SGID%3F,made%20in%20a%20particular%20course

[13] Chase, B. (2023, February 4). *Steps toward future: Science, technology, engineering and math*. Huron Plainsman. Retrieved February 22, 2023, from https://www.plainsman.com/article/steps-toward-future-science-technology-engineering-and-math

[14] Admissions. (n.d.). *The Science of Pottery and Glass*. South Dakota Mines. Retrieved February 22, 2023, from https://apply.sdsmt.edu/register/pottery/

[15] *Art + Engineering Workshop*. Art and Engineering. Retrieved February 22, 2023, from https://sites.google.com/sdsmt.edu/art-and-engineering/art-engineering-workshop